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ORIGINAL PAPER

Impact of mining on tree diversity of the silica mining forest area at Shankargarh, Allahabad, India

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Abstract: The Shankargarh forest area is rich in silica, a major mineral used in glass industry. Extensive open cast silica mining has severely damaged the forest as well as productivity of the region. An understanding of the impact of mining on the environment particularly on vegetation characteristics is a prerequisite for further management of these mining sites, especially in the selection of species for reclamation works. The present paper deals with the study of the tree composition of silica mining area of Shgankargarh forest, at both disturbed and undisturbed sites. Tree vegetation study was conducted at undisturbed and disturbed sites of Shankargarh forests using standard quadrate method. Density, abundance and frequency values of tree species were calculated. Species were categorized into different classes according to their frequency. The importance value index (IVI) for each species was determined. Species diversity, Concentration of dominance, Species richness and Evenness index were calculated for the undisturbed and disturbed sites. The distribution pattern of the species was studied by using Whitford's index. Similarity index between tree composition of disturbed and undisturbed sites was determined by using Jaccard's and Sorenson's index of similarity. Tree species showed a drastic reduction in their numbers in disturbed sites compared to that of the undisturbed sites. The phytosociological indices also illustrated the impact of mining on the tree composition of the area. The present study led to the conclusion that resultant tree vegetation analysis can be used as important tool for predicting the suitability of particular species for revegetating the mined areas.

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Introduction

The earth resources are extensively exploited to improve the quality of life. Mining operations involving the extraction of minerals from the earth's crust is second only to agriculture as the world's oldest and important activity. Mining operations tend to make a notable impact on the environment (Bell et al. 2001). And it causes massive damage to landscapes and biological communities of the area (Sarma 2005). Natural plant communities get disturbed, and the habitats become impoverished due to mining. The Shankargarh area (a part of Allahabad District of Uttar Pradesh State of India) is famous for its Silica mines and the quality of the silica deposits found in the Shankargarh area. Silica, a mineral, is used in glass industry. An extensive quarrying and open cast mining of the area have resulted in long barren, unproductive and deeply irregular sloppy lands, and great damage to the forest as well as productivity of the region. Therefore, the reclamation of this mining area becomes a priority to counter environmental hazards and to restore the ecological balance. Restorations of these mined areas are usually hampered by the lack of basic information on the wide variety of native tree species that characterize these forests. The status regarding ecology of disturbances and natural recovery is also required to design effective restoration programs. Moreover, for reclamation works, proper selection of the species is a critical step that will adapt with the climatic and local soil condition (Maiti et al. 2006). The present work was conducted to the study of the tree composition of the silica mining area of Shankargarh forest, both at the disturbed and undisturbed site with an aim to choose ecologically compatible, economically viable and environmental stress tolerant species and to elucidate the difference in tree composition between disturbed and undisturbed sites.

Material and methods

The vegetation survey was conducted at undisturbed compartments of nearby forest of silica mining site (at Garwa block and Tandan Van) and disturbed site both (Fig. 1), by using standard quadrate method (Srivastava 2001) during peak growth season in September and October. The disturbed sites account for the area adjacent to the active mining site where active mining operation is going on. These sites were located at Bhaisahai Block, Kachari Block, Shivrajpur Block and Garawa Block of the Shakargarh Forest Range. For tree component, quadrates of 10 m × 10 m size were laid randomly. Ten replications were taken in both cases (disturbed and undisturbed sites). The tree species found in the quadrates were identified. Quantitative community characteristics such as frequency, density, abundance and importance value index (IVI) of each species were determined, following the methods as described by Misra (1968). The importance value index (IVI) for each species was determined as the sum of the relative frequency and relative density only which were calculated by using the following formula (Kohli et al. 2004). The density and frequency values of recorded species were calculated and resultant frequency values were classified into frequency classes, viz.: class A (1%–20%), class B (21%–40%), class C (41%–60%), class D (61%–80%) and class E (81%-100%). Species diversity (Shannon and Weiner, 1963), Concentration of dominance (Simpson, 1949), Species richness (Margalef 1978) and Evenness index (Pielou 1966) were calculated for undisturbed and disturbed sites. The distribution pattern of the species was studied by using Whitford's index (Whitford 1948). Similarity index between tree composition of disturbed and undisturbed sites was determined by using Jaccard's and Sorenson's index of similarity (Sorenason 1948; Krebs 1999).

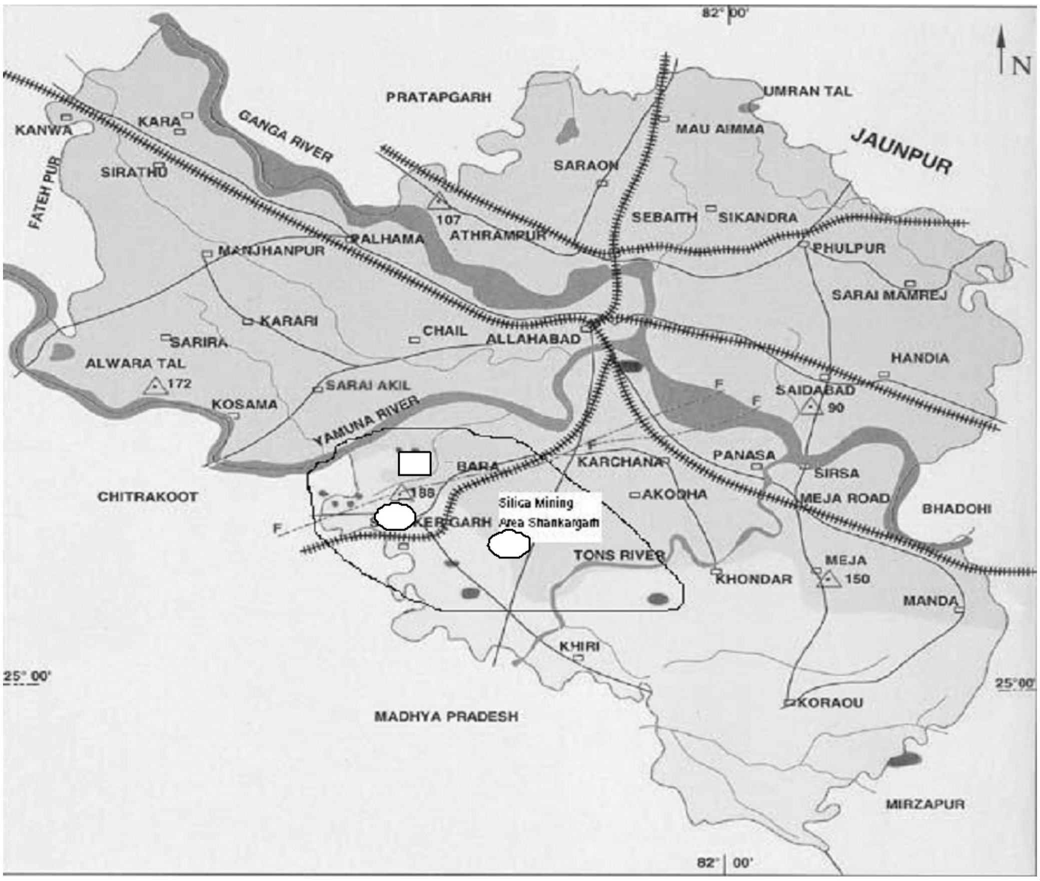

Fig. 1 Location of disturbed (flat rectangle shapes) and undisturbed (flat oval shapes) forest area at Shankargarh Silica Mining area, Allahabad

Results and discussion

Vegetation analyses

The tree vegetation characteristics of the disturbed area were compared with that of an adjacent undisturbed forest of the area. Plant species diversity of tree was more in undisturbed forest of the area than that in the disturbed area.

The density per quadrate, frequency values, frequency class, abundance, importance value index (IVI), Whitford's index and local names of each tree vegetation at undisturbed forest area and disturbed area are shown in Table 1 and 2 respectively. At undisturbed forest area, the most dominating tree species of the area was *Butea monosperma* with the highest IVI value followed

by *Flacourtia indica. Prosopis juliflora*, *Dalbergia sissoo*, *Acacia catechu* and *Acacia nilotica* were also the major species of the area. *F. indica* shows regular distribution pattern with 0.023 Whitford index. Whereas, other tree species shows random distribution pattern having Whitford index ranging from 0.025 to 0.05. Whereas, in case of tree vegetation of disturbed area, *B. monosperma* and *F. indica* have almost similar IVI value, i.e. 51.65 and 51.28 respectively, and they have the community structure equally. In this case, *B. monosperma* shows a regular distribution pattern with Whitford's index value<0.025, whereas, *F. indica* had a random distribution pattern. *A. catechu* and *L. parviflora* were other major species of the area showing contagious or clumped distribution pattern (Table 2). The high importance value of *B. monosperma* represents its dominance in disturbed areas and shows its ability to grow in the disturbed environments and its dominance in the harsh conditions. The similar ecology of *B. monosperma* was also documented by Orwa et al. (2009) that *B. monosperma* is a tree of tropical and subtropical climate. *B. monosperma* is found throughout the drier parts of India, often gregarious in forests, open grasslands and wastelands. It is resistance to browsing and can grow in the open grounds disturbed with biotic interferences like grazing and other man made interferences. This escaping extermination is owing to its ability to reproduce from seed and root suckers. It can grow on a wide variety of soils including shallow and gravelly sites. The tree is very drought resistant and frost hardy and can thrive in disturbed environment (Orwa et al. 2009; Hocking, 1993).

Table 1. Tree Species at silica mining area of Shankargarh in the undisturbed forest area:

Tree species	Family	Local name	Frequency (%)& class*	Density/quadrate	Abundance	IVI	Whitford' s index
Flacourtia indica	Flacourtiaceae	Baichi, Kataiya	80 D	1.5	1.88	18.671	0.0234
Madhuka indica	Sapotaceae	Mahua	40 B	0.5 0	1.25	7.792	0.0313
Azadirachta indica	Meliaceae	Neem	40 B	0.60	1.50	8.410	0.0375
Albizia procera	Mimosaceae	Safed siris	40 B	0.60	1.50	8.410	0.0375
Butea monosperma	Fabaceae	Dhak, Palash	90 E	2.10	2.33	23.551	0.0259
Acacia nilotica	Mimosaceae	Babool	50 C	0.90	1.80	11.438	0.0360
Pithecellobium dulce	Mimosaceae	Jungle jalebi	40 B	0.70	1.75	9.027	0.0438
Eucalyptus hybrid	Myrtaceae	Nilgiri	40 B	0.70	1.75	9.027	0.0438
Mangifera indica	Anacardiaceae	Am	20 A	0.20	1.00	3.588	0.0500
Emblica officinalis	Euphorbiaceae	Aonla	50 C	0.90	1.80	11.438	0.0360
Acacia leucophloea	Mimosaceae	Rehuja,Safed kikar	70 D	1.20	1.71	15.643	0.0245
Dalbergia sissoo	Fabaceae	Shisham	50 C	1.20	2.40	13.290	0.0480
Prosopis juliflora	Mimosaceae	Kathaila	50C	1.50	3.00	15.142	0.0600
Acacia catechu	Mimosaceae	Khair	40 B	1.20	3.00	12.113	0.0750
Pongamia pinnata	Fabaceae	Karanj, Kanji	40 B	0.60	1.50	8.410	0.0375
Lagerstroemia parviflora	Lythraceae	Asidh, Dhaudi	50 C	1.00	2.00	12.055	0.0400
Diospyros melanoxylon	Ebanaceae	Tendu	30 B	0.40	1.33	5.999	0.0444
Ficus relegiosa	Moraceae	Peepal	30 B	0.40	1.33	5.999	0.0444

*Frequency classes: A = 1%–20%, B=21%–40%, C=41%–60%, D=61%–80%, E=81%–100%.

Table 2. Tree Species at silica mining area of Shankargarh at disturbed site

Tree species	Family	Local name	Frequency (%) & class*	Density/quadrate	Abundance	IVI	Whitford' s index
Flacourtia indica	Flacourtiaceae	Baichi, Kataiya	70 D	1.5	2.14	51.29	0.031
Butea monosperma	Fabaceae	Dhak, Palash	90 E	1.2	1.33	51.65	0.015
Acacia leucophloea	Mimosaceae	Rehuja,	20 A	0.3	1.50	12.13	0.075
Holoptelia integrifolia	Ulmaceae	Chilbil, Kanju	10 A	0.1	1.00	5.09	0.100
Acacia catechu	Mimosaceae	Khair	30 B	0.5	1.67	19.18	0.056
Emblica officinalis	Euphorbiaceae	Aonla	10 A	0.1	1.00	5.09	0.100
Azadirachta indica	Meliaceae	Neem	20 A	0.3	1.50	12.13	0.075
Lagerstroemia parviflora	Lythraceae	Asidh, Dhaudi	30 B	0.6	2.00	21.14	0.067
Magifera indica	Anacardiaceae	Am	30 B	0.3	1.00	15.26	0.033
Jtropha curcas	Euphorbiaceae	JatrophaBiodiesel plant	10 A	0.2	2.00	7.05	0.200

*Frequency classes: A = 1%–20%, B=21%–40%, C=41%–60%, D=61%–80%, E=81%–100%.

Higher importance value of *F. indica* also indicated its ability to grow in the degraded environment. The ecology of *F. indica* was also documented by Orwa et al. (2009) that *F. indica* is common in tropical dry deciduous, thorn forests and bush lands. The species is drought resistant and can grow on variety of soil including poor soils like lime stone and sandy soils. The dominance of one or two species in disturber area explains the low diversity and high dominance in the mined affected areas.

Plant populations exhibit three patterns of spatial distribution, viz.: contagious or clumped, and random, regular or uniform. Patchiness, or the degree to which individuals are aggregated or dispersed, is crucial to the understanding of how species uses resources, and how it is used as a resource. Besides, the distribution pattern of species population is often related to its productive biology. Webb et al. (1967), Ashton (1972) and Austin et al. (1972) indicated that in the absence of major disturbance, soil and water conditions play major roles in controlling species distribution pattern. The contagious distribution pattern of species indicates the mosaicness of the forest stand. The contagious of the species suggests the increase in fragmentation and patchiness of the natural vegetation due to mining. Similar species distribution pattern was observed by Sarma (2002, 2005) in the coal mining areas of Nokrek biosphere reserve of Meghalaya.

Species Diversity

A good number of leguminous species was observed on undisturbed site in comparison to the disturbed site, which is an indication of enriched fertility status of the soil at undisturbed site. This finding is in concurrence with the findings of Benarjee et al. (2000). Since the mined and nonmined areas have the similar climatic, edaphic and physiographic features the differences in species composition could be attributed to the mining activities. This is in agreement with the findings of Das Gupta (1999), Baig (1992), Jha and Singh (1992). Sarma (2002), while studying the impact of coal mining on the vegetation characteristics of the Nokrek Biosphere Reserve of Meghalaya, outlined that the composition of vegetation reduces in the mined areas with that of the adjacent unmined areas.

Total species, genera, family, total density, Simpson Dominance Index, Shannon-Weaver index for species diversity, Species richness (Margalef Index), and Evenness Index (Pielous Index) for disturbed and undisturbed sites, are given in Table 3. The tree species showed a drastic reduction in their number in disturbed sites with that of the undisturbed sites. In the undisturbed site, 18 tree species belonging to 16 genera and 11 families were present. There were total 10 tree species belonging to 9 genera and 8 families were recorded in the disturbed areas. The undisturbed areas have greater plant density compared to that of the disturbed areas because of the moisture stress and nutrient deficient soil. Low growth form, sparse density and ability to tolerate low nutrient levels, and low moisture conditions are probably the adaptations to the harsh physical nature of substrate. Lyngdoh (1995), Das Gupta (1999) and Sarma (2002) works lend support to the present findings.

Shannon-Weaver indices for species diversity showed much variation with respect to the disturbed and undisturbed sites. Shannon-Weaver index of diversity for tree species was much lower in the disturbed areas compare to undisturbed area representing that the diversity was reduced in the disturbed areas and also suggests the dominance of one or two species in the disturbed area. Similar findings were reported by Raizada and Samra (2000). They reported that diversity (H') of tree species in the natural forest was higher than the rehabilitated area. Concentration of dominance or Simpson Dominance Index, as expected, showed inverse relationship with the diversity index and had a higher value for disturbed site in comparison to that of undisturbed site. The Evenness Index (Pielous Index) did not show much variation with respect of the both, disturbed and undisturbed area. A higher Margalef Index for species richness was reported for undisturbed area in comparison to disturbed area. This is in concurrence with the finding of Sonakar et al. (2005). They reported a higher diversity index, species richness and lower concentration of dominance for the ground flora under plantation than that of unplanted barren land.

Table 3. Species, family compositions and phyto-sociological parameters of tree vegetation at the disturbed and undisturbed site

Parameters	Undisturbed Site	Disturbed Site
No. of species	18	10
No. of genera	16	9
No. of family	11	8
Density (individuals/100 m^2)	16	5
Simpson Dominance Index	0.0657	0.1685
Shannon-Weaver index	1.217	0.869
Species richness (Margalef index)	3.209	1.698
Evenness Index (Pielous index)	0.421	0.378

The Sorensons Index of similarity for tree vegetation was 0.5714 (dissimilarity = 0.4286) between the disturbed and undisturbed site. Whereas, the Jaccard's Index of similarity for tree vegetation was 0.4 (dissimilarity = 0.6) between the disturbed and undisturbed site. The Jaccard and Sørensen indices emphasize differences and similarities, respectively; however, their behavior was almost identical. In case of Jaccard's index the difference was more pronounced. This was in concord with the findings reported by Verma et al. (2000).

Dominance-diversity curve

Dominance-diversity curves were used to interpret the dominance of species in the community in relation to resource apportionment and niche space (Whittaker 1975). According to Whittaker (1965), the log normal series describes the partitioning of realized niche space among various species, and it is the consequence of the evolution of diversity in the species along the niche parameters that it exploits. The curve for tree species (Fig. 2) in the undisturbed sites resembles the lognormal curve; therefore, it suggests that there was more or less an even apportion-

ment of resources among the members of the important species. The curves for the disturbed site resemble with broken-stick series model (Poole 1974). This could be attributed to the lesser number of species occurring in these areas and also represent a stressed environment where conditions were not favorable for plant growth. Species diversity was low on these stands, but the species that grow here appear to have developed tolerance that enables them to grow in such an environment. This finding reiterates with the finding of Sharma (2002).

Conclusion

Vegetation potential of any area is dependent upon physical environmental limitations and edapho-biotic components and their interaction, soil surface characteristics, climate and vegetation after open-cast mining. Individual species success and community composition are governed by local site variables. The substrate conditions on individual mine sites act as an environmental sieve' (Harper and White 1970; Nath 2004). Most suited species are able to establish and become an important component of the community. In present study, due to extensive silica mining, large areas of the Shankargarh forest area have been turned into degraded forest, creating unfavorable habitat conditions for plants and animals. The unfavorable habitat conditions prevailing in the mined areas have reduced the chances of regeneration of many a species, thereby, leading to reducing the number of species in the mined areas. The present study shows that phytosociological analysis can be used as important tools for predicting the suitability of mined habitats for the plant growth. The information gathered on various aspects of local vegetation and colonization of plants would be helpful in revegetating the mined areas.

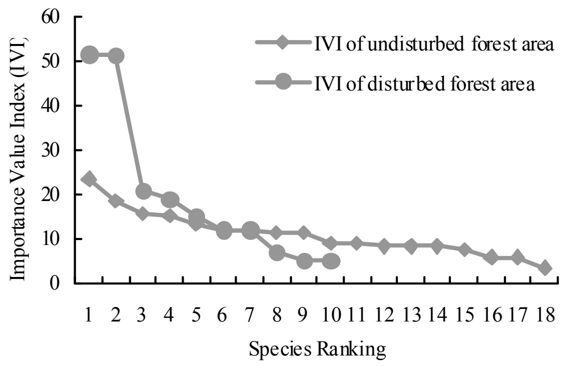

Fig. 2 Dominance-diversity curves of trees in disturbed and undisturbed forestareas

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References

Ashton, P. S. 1972. The Quaternary geomorphological history of western Malesia and lowland forest phytogeography. In P. S. and M. Ashton (eds.), *The Quaternary era in Malesia, Transactions of the Second Aberdeen-Hull Symposium on Malesian Ecology*, 1971. Hull (UK). University of Hull Department of Geography Miscellaneous Series 13, pp. 35–62.

Austin MP, Ashton PS, Smith PG. 1972. The application quantitative methods to vegetation survey III. A re-examination of rain forest data from Brunei. *Journal of Ecology*, **60**: 305–324.

Baig MN. 1992. Natural revegetation of coal mine spoils in the rocky mountains of Alberta and significant for species selection in land restoration. *Mountain Research and Development*, **12**(3): 285–300.

Banerjee SK, Mishra TK; Singh AK. 2000. Restoration and reconstruction of coal mine spoils: an assessment of time prediction for total ecosystem development. *Advances in Forestry Research in India*, **23**: 1–28.

Bell FG, Bullock SET, Halbich TFJ, Lindsey P. 2001. Environmental impacts associated with an abandoned mine in the Witbank Coalfield, South Africa. *International Journal of Coal Geology*, **45**: 195–216.

Das Gupta S. 1999. Studies on vegetal and microbiological processes in coal mining affected areas. Ph.D. Thesis. North_Eastern Hill University, Shillong. India.

Hocking D. 1993. *Trees for Drylands*. New Delhi: Oxford & IBH Publishing Co..

Jha AK, Singh JS. 1992. *Restoration of Degraded Land: Concepts and Strategies* (ed. Singh, J. S.), Rastogi Publication Meerut, pp. 212–254.

Kohli RK, Dogra KS, Batish DR, Singh HP. 2004. Impact of Invasive Plants on the Structure and Composition of Natural Vegetation of Northwestern Indian Himalayas. *Weed Technology*, **18**(SP1): 1296–1300.

Krebs CJ. 1999. *Ecological methodology*. 2nd. ed. Menlo Park, CA: AddisonWesley Longman.

Lyngdoh T. 1995. Community dynamics and edaphic changes in relation to coal mining in Jaintia Hills, Meghalaya. Ph.D. Thesis, North-Eastern Hill University, Shillong, India.

Maiti SK, Shee C, Ghose MK. 2006. Selection of plant species for the reclamation of mine degraded land in the Indian Context. *Land Contamination & reclamation*, **14**(2): 1–14.

Margalef FR. 1978. Information theory in ecology. *Gen Syst*, **3**: 36–71.

Misra R. 1968. Ecology Work Book. Oxford & IBH Publication, New Delhi.

Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A. 2009. Agroforestree Database: A tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/af/treedb/)

Pielou EC. 1966. The measurements of diversity in different types of biological collections. *J Theor Biol*, **13**: 131–144.

Poole RW. 1974. *An introduction to quantitative ecology*. Tokyo: Mc Graw Hill. Kogakusha..

Raizada A, Samra JS. 2000. Rehabilitation of an abandoned limestone mine in the lower western Himalayas -- impact assessment on vegetation development and floristic diversity. *Indian-Forester*, **126**(8): 842–855.

Sarma K. 2005. Impact of coal mining on vegetation: a case study in Jaintia Hills District of Meghalaya, India. Thesis for partial fulfilment of the re-

quirements for the degree of Master of Science International Institute For Geo-Information Science And Earth Observation Enschede, The Netherlands.

Sarma K. 2002. Coal mining and its impact on environment of Nokrek Biosphere Reserve, Meghalaya. Ph.D. Thesis. North-Eastern Hill University, Shillong. India.

Shannon CE, Weiner W. 1963. The Mathematical Theory of Communication, University of Illinois Press, Urbana, USA.

Simpson EH. 1949. Measurment of diversity. *Nature*, **163**: 688.

Sorenson T. 1948. A method of establishing groups of equal amplitude in a plant society based on similarity of species content. *K Dan Vidensk Selsk*, **5**: 1–34.

Sonakar SD, Tripathi SP, Nandeshwar DL, Nain NPS. 2005. Ground flora diversity and productivity under the plantations of different tree species in degraded land. *Indian J Trop Biodiv*, **13** (1): 20–28.

Srivastva H N. 2001. Practical Botany. Pradeep Publications, Jalandhar.

Verma RK, Shadangi DK, Totey NG. 2000. Effect of Dalbergia sissoo (Roxb.) and Dendrocalamus strictus (Roxb.) plantations on enhancement of biological diversity in drgraded land. *J Trop For*, **16**: 36–44.

Webb CJ, Tracey JG, Williums WT, Lance GN. 1967. Studies in the numerical analysis of complex rain forest communities 1. A comparison of methods, applicable to site/ species data. *Journal of Ecology*, **55**: 171–191.

Whitford PB. 1948. Distribution of woodland plants in relation to succession and clonal growth. *Ecology*, **30**: 199–208.

Whittakker RH. 1965. Dominance and diversity in land plant communities. *Science*, **14**: 250–259.

Whittakker RH. 1975. Communities and ecosystems. New York: Mc Milan Publishing Company,.